

PATENT
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SCAN-MODE INDICATION TECHNIQUE FOR AN INTEGRATED CIRCUIT

by

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BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an integrated circuit technique, and, more particularly, to a technique for testing an integrated circuit. More specifically, the present invention relates to a technique for indicating an integrated circuit to enter a scan mode.

Description of Related Art

[0002] A full scan operation is a critical production test feature for an integrated circuit. However, an integrated circuit needs to be able to switch from a normal operational mode to a scan mode. However, entry of an integrated circuit into scan mode must be controlled in such a way that the part is not accidentally placed into scan mode.

[0003] The simplest way of accomplishing such scan mode control is to provide a dedicated pin on the integrated circuit for such an operation. **Figure 1** shows an integrated circuit **100** with a dedicated scan mode pin **102** according to the prior art. Scan mode pin **102** is solely reserved for signaling the integrated circuit into a scan mode. Larger chips, such as a system-on-a-chip, can accommodate a dedicated scan mode pin since it has extra pins to spare. However, smaller chips, such as small mixed-signal chips, typically have pin counts in the order of eight to twenty-eight pins, generally without any pins to spare.

[0004] A technique for providing scan mode control without requiring a dedicated or additional pin is shown in **Figure 2**. **Figure 2** shows an integrated circuit **200** with an N-bit bus **201** coupled to an N number of pins **202a, 202b, ...202N**, which are already existing pins and are not dedicated to scan mode, according to the prior art, and in which N is a positive integer. Pins **202a, 202b,...202N** are static mode pins. Static mode pins are pins that are either typically hard tied to a supply/ground or change in value only during global reset or power-down (e.g. do not change in value during normal

operation) of integrated circuit **200**. The technique involves using unused or a reserved combination of pins **202a**, **202b**,... and/or **202N**, which then signals integrated circuit **200** to enter into scan mode. A disadvantage of this technique is that the unused/reserved combination of pins **202a**, **202b**,...
5 and/or **202N** used for indicating integrated circuit **200** for entering scan mode can no longer be used for some other operation, feature, mode, or purpose that may be added in the future. Another disadvantage is that some level of fault coverage on the combinational logic that the input pins directly drive may be lost.

10 [0005] Another prior art technique for providing scan mode control without requiring a dedicated pin is shown in **Figures 3A** and **3B**. **Figure 3A** shows an integrated circuit **300** with a control port **304** having a control port register (REG) **306** in which one of the bits in REG **306** is the scan mode indicator according to the prior art. A microcontroller **302** for controlling control port
15 **304** is coupled to control port **304**. Integrated circuit **300** also has a reset pin **RST**. **Figure 3B** shows a detailed diagram of control port register (REG) **306** according to the prior art. REG **306** has a number of flip flops **308A**, **308B**, **308C**, and **308D**. Flip flop **308C** is designated as the flip flop to provide the scan mode indicating bit.

20 [0006] Each of flip flops **308A**, **308B**, **308C**, and **308D** has an input **D**, an output **Q**, and a reset input that receives the reset signal from reset pin **RST**. Each of flip flops **308A**, **308B**, and **308D** also has an input **SCAN_IN**. As shown in **Figure 3B**, flip flop **308A** receives data input **D** and provides output **Q** as the input **SCAN_IN** to flip flop **308B**. Flip flop **308B** also receives
25 respective data input **D** and, in turn, provides output **Q** as the input **SCAN_IN** to flip flop **308D**. Flip flop **308C** is the scan mode indicating flip flop. An OR gate receives as inputs the fed-back output **Q** of flip flop **308C** and the data input **D** that would normally be directly fed as input **D** into flip flop **308C**. The output of the OR gate is instead fed as the input **D** into flip flop **308C**. Flip flop
30 **308C** provides output **Q** as the **SCAN_MODE** signal. As an example, if **SCAN_MODE** signal is low, then integrated circuit **300** operates in the normal

mode and normally-fed data input **D** is provided to flip flop **308C** (e.g., the data input **D** ORed with a low **SCAN_MODE** signal equals the data input **D**). However, if **SCAN_MODE** signal is high, then integrated circuit **300** is signified to operate in the scan mode (e.g., the data input **D** ORed with a high **SCAN_MODE** signal equals the high **SCAN_MODE** signal). The high **SCAN_MODE** signal is provided as input **D** into flip flop **308C**. The output of flip flop **308C** provides a signal indicating that integrated circuit **300** is to operate in the scan mode.

[0007] Since control port **304** is similar to other digital components and is also scanned in the scan mode, flip flop **308C**, which is associated with providing the scan mode indicating bit, must be set up and operated in an unique, particular way. As discussed earlier, the data logic value, input **D**, which normally is input directly to flip flop **308C**, is instead fed into an OR gate, and an OR operation is performed on this input **D** with the **SCAN_MODE** signal. The output of flip flop **308C** provides the scan mode indicator. Furthermore, flip flop **308C** should not be made part of the scan chain. Flip flop **308C** should be operated in this particular manner in order to ensure that integrated circuit **300** stays in the scan mode regardless of what the scan chain is doing. Integrated circuit **300** is able to exit scan mode through use of a global reset or powerdown signal since flip flop **308C** generally has an asynchronous reset that is connected to the global reset.

[0008] However, scan mode control through use of a control port register is limited especially in situations in which the hardware does not have a control port. Also, specific attention and effort needs to be focused on ensuring that the flip flop designated for scan mode indication is not made part of the scan chain. Furthermore, the scan tool is generally not programmed on how the integrated circuit will enter the scan mode. Thus, the correct tester pattern needs to be manually generated. The correct tester pattern writes to the control port and it is appended to the beginning of the scan pattern generated by an Automatic Tester Pattern Generation Tool. Also, since the reset pin **RST** can return integrated circuit **300** to the normal

operational mode when in the scan mode, faults on the reset line coupled to reset pin **RST** cannot be detected.

[0009] Thus, the present invention recognizes the desire and need for providing a simpler and improved technique for indicating an integrated circuit to enter the scan mode. The present invention further recognizes the desire and need to provide such a technique without having to utilize designated or additional pins of the integrated circuit. The present invention also recognizes the desire and need to provide a scan mode entry technique that avoids the use of a combination of pre-existing pins. The present invention additionally recognizes the desire and need of a scan mode entry technique that avoids the use of a control port and control port register. The present invention overcomes the problems and disadvantages in accordance with the prior art.

Summary of the Invention

[0010] An integrated circuit and method for indicating the integrated circuit to enter into a scan mode are disclosed. A designated signal, such as an analog supply signal, for an analog block of an integrated circuit is utilized for indicating entry of a digital block of the integrated circuit into a scan mode. Operations of the analog block and the digital block are generally independent from each other in scan mode. Prior to the digital block utilizing the designated signal, voltage rails for the designated signal are resolved to the voltage rails of a digital supply signal for the digital block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

[0012] **Figure 1** is a block diagram of an exemplary integrated circuit having a designated scan mode pin according to the prior art;

10 [0013] **Figure 2** is a block diagram of an exemplary integrated circuit having a combination of pins for indicating entry into scan mode according to the prior art;

[0014] **Figure 3A** is a block diagram of an exemplary integrated circuit having a control port with a control port register in which one of the bits is utilized to indicate entry into the scan mode according to the prior art;

[0015] **Figure 3B** is a more detailed block diagram of the control port register in **Figure 3A** according to the prior art;

[0016] **Figure 4** is a block diagram of an exemplary integrated circuit that utilizes a supply of an analog block to indicate the digital block to enter into the scan mode according to the present invention;

20 [0017] **Figure 5** is a block diagram of an exemplary integrated circuit that has a first independent block that is generally independent in operation from a second independent block when the second block is in a special mode and in which a signal designated for one purpose for the first independent block is generally utilized for putting the second independent block into the special mode;

[0018] **Figure 6** shows an exemplary inverter that can be used in the integrated circuits of **Figures 4 and 5**; and

[0019] **Figure 7** shows an exemplary NOR gate that can be used as the inverter in the integrated circuits of **Figures 4 and 5**.

DETAILED DESCRIPTION OF THE INVENTION

[0020] An integrated circuit and method for indicating the integrated circuit to enter into a scan mode are disclosed. A designated signal, such as an analog supply signal, for an analog block of an integrated circuit is utilized for
5 indicating entry of a digital block of the integrated circuit into a scan mode.

[0021] With reference now to **Figure 4**, an exemplary integrated circuit **400** is shown. Integrated circuit **400** has an analog block **402** and a digital block **404**. Digital block **404** utilizes an analog supply signal **VA+**, which is a designated signal for analog block **402**, in order to indicate entry of digital
10 block **404** into a scan mode. Operations of analog block **402** and digital block **404** are generally independent or mutually exclusive from each other in scan mode.

[0022] However, before digital block **404** can use the designated signal of analog block **402**, the voltage rails of analog supply signal **VA+** must be resolved to the voltage rails of a digital supply signal, such as digital supply
15 signal **VD**, of digital block **404**. Thus, integrated circuit **400** has an exemplary inverter **406**, which receives the analog supply signal **VA+** as its input, and provides an output signal to digital block **404**. The output signal from inverter **406** is the signal **SCAN_MODE** for indicating entry of digital block **404** into the
20 scan mode. Thus, inverter **406** resolves the voltage rails of analog supply signal **VA+** to voltage rails of a digital supply signal **VD** of digital block **404** by inverter **406** level shifting the voltage rails of analog supply signal **VA+** from analog block **402** to digital supply signal **VD** of digital block **404**.

[0023] Referring now to **Figure 5**, another exemplary integrated circuit
25 **500** is shown. Integrated circuit **500** shows that the present invention can be described in more generic terms. Integrated circuit **500** has an independent block **502** and another independent block **504** in which the operations of independent blocks **502** and **504** are generally independent or mutually exclusive when independent blocks **502** and **504** are operating in a special
30 mode. A signal **501** is solely designated for one purpose for independent

block **502**. Signal **501** of independent block **502** is also sent to independent block **504**. Independent block **504** uses signal **501** for another or different purpose.

[0024] However, before independent block **504** can use designated signal **501** of independent block **502**, voltage rails of signal **501** must be resolved to the voltage rails of another designated signal, such as signal **505**, of independent block **504**. Thus, integrated circuit **500** has an inverter **506**, which receives designated signal **501** as its input, and provides an output signal to independent block **504**. The output signal from inverter **506** is a signal **503** for indicating execution of another purpose or operation for independent block **504**. Thus, inverter **506** resolves the voltage rails of designated signal **501** of independent block **502** to voltage rails of another signal **505** of independent block **504** by inverter **506** level shifting the voltage rails from signals of independent block **502** to signals of independent block **504**. Integrated circuit **400** parallels integrated circuit **500** as follows: Analog block **402** is an independent block **502**; Digital block **404** is an independent block **504**; Inverter **406** is an inverter **506**; Analog supply signal **VA+** is a signal **501**; Digital supply signal **VD** is a signal **505**; Signal **SCAN_MODE** is a signal **503**.

[0025] Inverter **406** is now discussed in more detail. In one embodiment, integrated circuit **400** may be set up so that the scan mode is activated upon a high value. In this scenario, analog supply signal **VA+** of Figure 4 is set to a low analog value (e.g., low voltage rail of analog supply signal **VA+**). Inverter **406** inverts the low analog value of analog supply signal **VA+** to a high digital value (e.g., high voltage rail of digital supply signal **VD**). Inverter **406** provides the high digital value of signal **SCAN_MODE** to digital block **404**. The high digital value signifies that digital block **404** is to enter into the scan mode.

[0026] In another embodiment, integrated circuit **400** may be set up so that the scan mode is activated upon a low value. In this other scenario, integrated circuit **400** is generally the same in features and operation as

described earlier except that an additional inverter **408**, which is shown in dotted lines in **Figure 4**, is coupled between inverter **406** and digital block **404**. Inverter **408** inverts the high digital value to a low digital value (e.g., low voltage rail of digital supply signal **VD**), and the low digital value is fed to
5 digital block **404** to signify entry into the scan mode.

[0027] As one example, voltage rails for analog supply signal **VA+** are at zero volts and 2.5 volts while voltage rails for digital supply signal **VD** are at zero volts and 3.3 volts. If integrated circuit **400** is configured to trigger entry into scan mode based on an active high value, then the zero volt rail for
10 analog supply signal **VA+** needs to be resolved to the 3.3 volt rail of digital supply signal **VD** and the 2.5 volt rail of analog supply signal **VA+** needs to be resolved to the zero volt rail of digital supply signal **VD**. On the other hand, if integrated circuit **400** is configured to trigger entry into scan mode based on an active low value, then the zero volt rail for analog supply signal **VA+** is
15 resolved to the zero volt rail of digital supply signal **VD** and the 2.5 volt rail of analog supply signal **VA+** is resolved to the 3.3 volt rail of digital supply signal **VD**. The resolving of these voltage rails are accomplished by use of inverter **406** in the active high scenario and use of both inverters **406** and **408** in the active low scenario. In either scenario, latch up problems caused by the
20 transition from a voltage rail of analog supply signal **VA+** to a voltage rail of digital supply signal **VD** are avoided by the use of level shifters and/or buffers on the interface signals between analog block **402** and digital block **404**.

[0028] In the event that the high voltage rail of analog supply signal **VA+** is much smaller in value than the high voltage rail of digital supply signal **VD**
25 (e.g., high **VA+** = 2.5 volts and high **VD** = 5.0 volts), inverter **406** can be designed to have a trip point that is lower than its normal value. In other words, inverter **406** or **506** can be designed to trigger the inverting operation at a voltage value that is at a lower-than-normal value. With reference now to **Figure 6**, an exemplary inverter **600** is shown. Inverter **600** can be used as
30 inverter **406** in integrated circuit **400** or as inverter **506** in integrated circuit **500**.

[0029] Inverter **600** has transistor gates **602** and **604**. Normally, an inverter would have gates of generally equal size. Inverter **600** has been designed so that the widths of transistor gates **602** and **604** have been re-sized and so that inverter **600** has a trip point that is lower than an otherwise
5 normal value. Gate **602** has a width **w602** equal to m while gate **604** has a width **w604** equal to $m * n$ where m is an m number of gate measurement units and n is a positive integer multiple such that width **w604** is greater than width **w602**.

[0030] Referring now to **Figure 7**, an alternative inverter **700** can be used
10 instead of inverter **600** in the scenario that the high voltage rail of analog supply signal **VA+** is much smaller in value than the high voltage rail of digital supply signal **VD**. Inverter **700** can instead be used as inverter **406** in integrated circuit **400** or inverter **506** in integrated circuit **500**. Inverter **700** is basically a NOR gate having multiple inputs. All of the multiple inputs are tied
15 together and connected to analog supply signal **VA+** or signal **501**. Inverter **700** provides an output signal that is signal **SCAN_MODE** for integrated circuit **400** and signal **503** for integrated circuit **500**.

[0031] Thus, the present invention provides a simpler and improved technique for indicating an integrated circuit to enter the scan mode. The
20 present invention provides such a technique without having to utilize designated or additional pins of the integrated circuit. The present invention provides a scan mode entry technique that avoids the use of a combination of pre-existing pins. The present invention provides a scan mode entry technique that avoids the use of a control port and control port register. The
25 present invention avoids losing fault coverage on certain digital portions of the integrated circuit. The present invention overcomes the problems and disadvantages in accordance with the prior art.

[0032] While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in

the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.